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ABSTRACT

Two experiments investigated developmental differences in attention allocation and attention-sharing in a dual-task paradigm using Performance Operating Characteristics (POC) as an innovative data analysis method. In Experiment 1, attention allocation was assessed. Two visual detection tasks were presented to 20 second- and 11 fifth-graders who indicated whether a target on each display was present or absent. Baselines of single-task performance were equated for each individual. After practice trials in which tasks were presented concurrently, subjects received instruction for each of five experimental conditions, which had different emphasis ratios. Accuracy was measured for 12 practice and 48 test trials. Experiment 2 assessed attention-sharing. Again, second- and fifth-graders participated. Procedures were identical to Experiment 1 except that baseline durations were obtained while both tasks were presented, participants received practice trials for the concurrent task before they performed baseline procedures, and only one emphasis ratio was employed. Results indicated that fifth graders could allocate their attention to different emphasis levels, but second-graders did not. Second-graders had a significantly slower baseline than fifth-graders. However, there was no age difference in attention-sharing. The POC analysis, which used performance functions in which performance on one task was plotted as a function of performance on a second task, allowed a more precise assertion of attention allocation and demonstrated the need to equate the baselines in developmental studies. (Contains 20 references.) (KDFB)

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Attention-Sharing in Middle Childhood: An Analysis of Performance Operating Characteristics

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Overview

The goal of our research studies was to better characterize developmental differences in attention allocation (i.e., the ability to manipulate attention) and attention-sharing in a dual-task paradigm using Performance Operating Characteristics (POC) as an innovative way to analyze the data.

Past research using the dual-task paradigm has yielded conflicting results. As shown in Table 1, some research has suggested that developmental differences in both attention allocation and attention-sharing exist while others have not. Reasons for the mixed results include confusion of the terminology, methodological issues, and problematic statistical procedures. The terminology used for attention allocation has been metacognition, self-regulation, and executive control. Each has several different operational definitions which has led to different ways of measuring attention allocation and, not surprisingly, different conclusions. Ambiguous task instructions and the lack of controls for different individual capacity levels has been identified by Somberg and Salthouse (1982) and Guttentag (1989) as problematic. The use of difference scores in the dual-task paradigm has over-corrected for single-task ability (Ackerman, Schneider, & Wickens, 1984), been demonstrated to be less reliable than either of the original scores (Brainerd and Reyna, 1989), and likely to lead to regression-to-the-mean (Cohen & Cohen, 1975; Ackerman & Wickens, 1982).

Performance Operating Characteristics (POC) analysis was employed in our research in order to address dual-task performance. POC analysis uses performance functions in which performance on one task (e.g., Task A) is plotted as a function of performance on the second task (e.g., Task B). Typically, as the allocated resources increase for one task, the availability of resources for the other task decreases (Somberg & Salthouse, 1982). The benefits of using this alternative statistical procedure include: being able to explicitly measure attention allocation within the capacity sharing model with varying emphasis levels; accurately measuring the total potential performance region for divided attention; and obtaining a measure of dual-task cost without necessitating the use of difference scores.

The current research examines attention allocation and attention-sharing in second- and fifth-graders with a consideration of the issues discussed above. In this research, the baselines of single-task performance will be equated for each individual and POC analysis will be implemented as a statistical procedure which will allow a more careful examination of these attention control processes. Our predictions are: (1) attention-sharing will develop before attention allocation, and (2) developmental differences will exist in attention allocation.

Methods

Experiment 1: Attention Allocation

Participants

Twenty second- and eleven fifth-graders volunteered for participation from a local public elementary school.

Apparatus and Procedure

The procedure was adapted from Somberg and Salthouse (1982) in which two visual detection tasks were presented to participants who were required to respond whether a target on each display was present or absent. Each child was individually tested on a laptop computer using Microcomputer Experimental Laboratories (MEL) software. Accuracy was the dependent measure.

Task 1 (Task X). As shown in Figure 1, four X's appeared at each of the four corners of an imaginary rectangle centered on the computer screen. The target was a small line (.14 cm) extending from the vertex of one of the X's. The location of the target could be on any of the four vertices of the X or the four corners of the imaginary rectangle. Each of the sixteen possible target locations was an equally likely event.

Task 2 (Task +). As shown in Figure 2, four plus signs (+'s) appeared at each of the four corners of an imaginary rectangle centered on the screen which was concentric to the imaginary rectangle of Task X. The target was a small line (.10 cm) extending from one of the four vertices of the + or the four corners of the imaginary rectangle. Each position was equally likely to occur.

Session 1: Equating the Baselines. Participants were presented with each task in a single-task environment to familiarize them with each task. Baseline durations for the task were assessed using Task X alone. Stimulus durations were manipulated (+/- 100 msec) until each participant was operating at an accuracy level between 75 and 80% for detection in one task. Individual baselines control for different levels of capacity among participants in the second- and fifth-grades.

Session 2: Experimental Trials. Participants received 32 practice trials in which both tasks were presented concurrently. Trials resembled Figure 3 in which both Tasks X and + were presented. Following practice, participants received instructions for each of the five experimental conditions with emphasis ratios of 4:0, 3:1, 2:2, 1:3, and 0:4. Figure 4 depicts how this was employed. Twelve practice and 48 test trials were presented for each of the five experimental conditions and accuracy was measured. Conterbalancing was achieved by giving half the subjects in each age group the emphasis order mentioned above while the other half received the reverse order.

Experiment 2: Attention-Sharing

Participants

Twenty second- and 20 fifth-graders volunteered for participation from a local public elementary school.

Apparatus and Procedure

The apparatus and procedure were identical to the previous experiment except for three things: (1) the baseline durations for the task were obtained while both tasks were presented, (2) participants received practice trials for the concurrent task before they performed the baseline procedure, and (3) only the 2:2 ratio condition was employed.

Results

Experiment 1: Attention Allocation

Performance Operating Characteristics (POC) Analysis

POC analysis is a method in which divided attention cost is determined in a dual-task environment. First, accuracy data from the two tasks are plotted along the x- and y-axes ranging from the minimum to maximum values. If there are no divided attention costs, then the three intermediary points would be located at the upper-right corner of the POC graph. To the extent that there are divided attention costs, the three intermediary points would be located down and to the left of the upper-right point. As shown in Figure 5, the area of this region is the divided attention cost (DAC). The total area of the entire rectangle is termed the functional performance region (FPR). The area of the FPR is calculated by computing the area of the rectangle produced in the graphs. The FPR signifies the potential dual-task performance.

The POC graphs for second- and fifth-graders are shown in Figures 6 and 7. The areas of the FPR and DAC were calculated for each group. The FPR regions were 193.20 and 1183.82 units for second- and fifth-graders, respectively. The relative DAC regions were 78.36 and 68.40 units of FPR, which is in the expected direction.

In a study conducted on age differences among younger and older adults (Somberg & Salthouse, 1982), young adults were found to have 1330.7 FPR units and 42.00 DAC units of FPR while the older adults were found to have 1296.7 FPR units and 42.00 units of FPR. Figure 8 illustrates data for a recently conducted experiment on young adults, where it was found that they were operating with 2310 FPR units and 90.12 DAC units of FPR. In comparing the FPRs, although the data from Somberg and Salthouse (1982) are similar to the data of the fifth-graders, data from recent adult participants demonstrate a larger range in the FPR. In comparing the DAC regions, it appears that the data from Somberg and Salthouse (1982) exhibit less cost than either the second- or fifth-graders. However, in our study with adults, there appears to be more cost. Further comparisons could not be made as the individual data did not meet the assumption of being a "monotonically increasing function of the amount of capacity allocated to a process" (Kantowitz & Weldon, 1985, p. 532).

Analysis of Variance

A two factor ANOVA for each task was also employed on the data (Grade X Condition). For both Tasks X and +, respectively, there was a Condition main effect, $F_{(4,116)} = 6.96$, $p < .0001$; $F_{(4,116)} = 14.26$, $p < .0001$, and an interaction of Grade X Condition, $F_{(4,116)} = 2.62$, $p < .05$; $F_{(4,116)} = 5.10$, $p < .001$. Further analysis revealed no differences among any of the emphasis levels for either task for second-graders. However, there were several significant differences among the emphasis levels for the fifth-graders in both tasks. As illustrated in Figure 9, it appears that the fifth-graders were able to manipulate their attention to emphasis levels. In contrast, second-graders in both Tasks X and + did not demonstrate differential attention performance as a function of the emphasis levels.

Figure 10 shows the results of the adults for Tasks X and +. As expected, adults were also able to manipulate their attention to emphasis levels on both tasks (Task X: $F_{(4,172)} = 23.82$, $p < .001$; Task +: $F_{(4,172)} = 29.83$, $p < .001$. All comparisons were significant except for one for Task X (25:0) and two for Task + (50:25, 25:0).

Baselines

Different levels of capacity for the two grades was examined using a t-test comparing the baseline durations. Second-graders were found to have a significantly slower baseline (M = 1725.00) than fifth-graders (M = 1344.44), $t_{(29)} = 4.57$, $p < .001$. Figure 11 depicts the baselines for the adults (M = 1006.25) in relation to the baselines for the second- and fifth-graders, $F_{(2,43)} = 28.09$, $p < .001$. The baseline for adults was faster than for either the second- or fifth-graders.

Experiment 2: Attention-Sharing

Analysis of Variance

A one-way ANOVA was performed on accuracy for Task X and Task + in which the 50:50 condition was compared between second- and fifth-graders. There was no difference found for either task, $F_{(2,49)} < 1$. Figure 12 compares the result of this experiment to the 50:50 condition from experiment 1 for both second- and fifth-graders as well as the 50:50 condition from the adults. It should be noted that these data for attention-sharing (50:50) were obtained from one condition of the five experimental conditions.

Baselines

Different levels of capacity for the two grades were examined using a t-test between the baseline durations for second- and fifth-graders. Second-graders had a slower baseline duration (M = 1775.00) than the fifth-graders (M = 1417.65), $t_{(35)} = 4.28$, $p < .001$. Figure 13 illustrates the baseline durations for second- and fifth-graders and compares them to the baselines obtained from adults. In a one-way ANOVA, baselines were found to be significantly different, $F_{(2,49)} = 36.52$, $p < .001$, where the baseline for adults was faster than for either the second- or fifth-graders.

General Discussion

The results of these studies on attention-sharing and attention allocation demonstrate the existence of developmental differences in attention allocation and no developmental differences in attention-sharing. Performance Operating Characteristics analysis allowed a more precise assertion of attention allocation and demonstrated the necessity of individually equating the baselines in developmental studies. Future studies which build on these findings are needed to identify the mechanisms and strategies underlying the ability to successfully manipulate the allocation of attention.

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TABLE 1

Methodological Issues and Developmental Differences

Study	Subject ages	Tasks: 1 & 2	Task baselines	Task emphasis	Equation of baselines	Time-sharing dev. diff.	Attn allctn dev. diff.
Birch (1976)	7, 10, 13	Sa-diff Tracking	YES YES	•1 Task & •Equal	NO	YES	YES & NO
Birch (1978)	8, 13	Sa-diff Tracking	YES YES	Equal	YES (practice)	NO	N/A
Hiscock & Kinsbo. (1978)	3-12	Recitation Tap	NO YES	Ambiguous	Indirectly (practice)	YES	N/A
Lane (1979)	7, 9, college	Visual mem. Auditory tracking	YES YES	Tsk 1&2 Stimuli	YES amt of stimuli	NO	YES
Manis Keating & Morrison (1980)	8, 12, 20	Sa-diff Probe detection	YES NO	Only 1 Task	YES, but not systematic	YES	N/A
White & Kinsbo. (1980)	3-12	Recitation Tap	NO YES	Ambiguous	NO	YES	N/A
Guttent. (1984)	7, 8, 11	Recall Tap	NO YES	Only 1 Task	NO	E1:YES E2&3: NO	N/A
Hiscoc. Kinsbo. Samuels & Krause (1985)	6-10	Recitation Tap	YES YES	Ambiguous	Indirectly (practice)	YES: Tsk1 vs 1&2 NO:Tsk2 vs 1&2	N/A
Schiff & Knopf (1985)	9-13	Detection Visual memory	YES YES	Only 1 Task	YES pilot data	YES	N/A
Kamhi & Masters. (1986)	3, 5, 7, 9	Speech Tap	YES YES	Ambiguous	NO	YES	N/A
Halford Maybery & Bain (1986)	3-5	Transcript-ion reasoning Color recall	YES NO	Ambiguous	Indirectly (practice)	YES (E2)	N/A
Bjorklu. & Harnish. (1987)	9, 12, 21	Recall Tap	NO YES	Ambiguous	NO	NO	N/A
Kee & Davies (1988) Exp 1	11, college	Tap Memorization (aloud)	YES NO	Ambiguous	NO	NO	N/A
Kee & Davies (1988) Exp 2	Same	Tap Memorization (silent)	Same	Same	Same	YES	N/A

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Figure 1

Figure 2

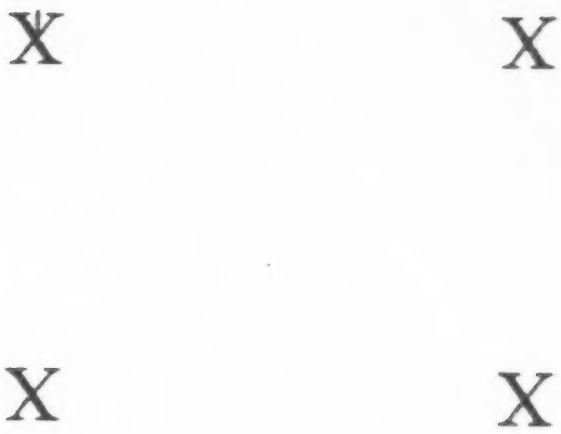
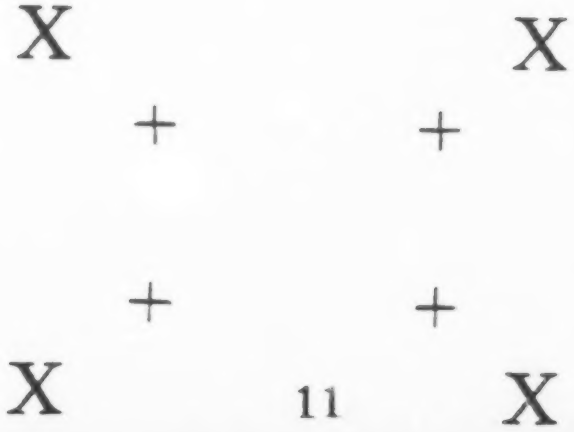


Figure 3



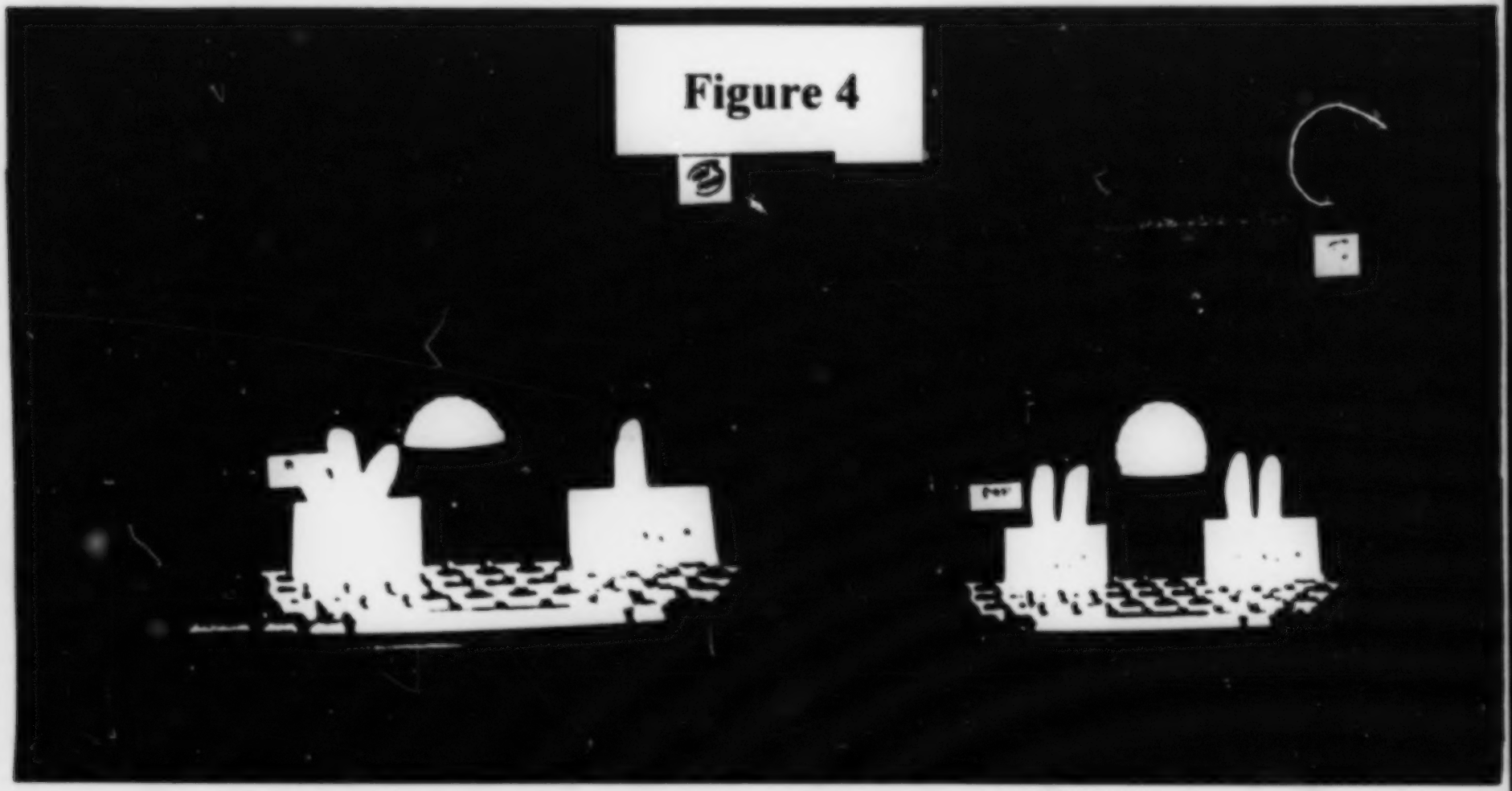


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Figure 5

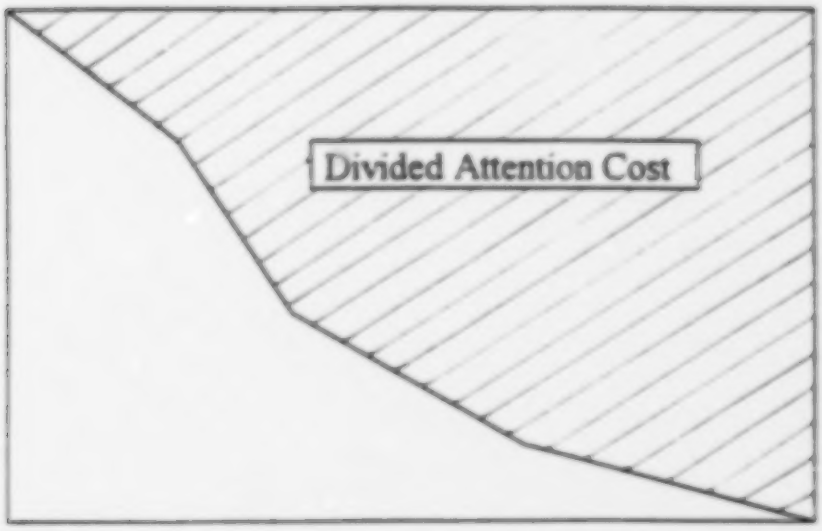
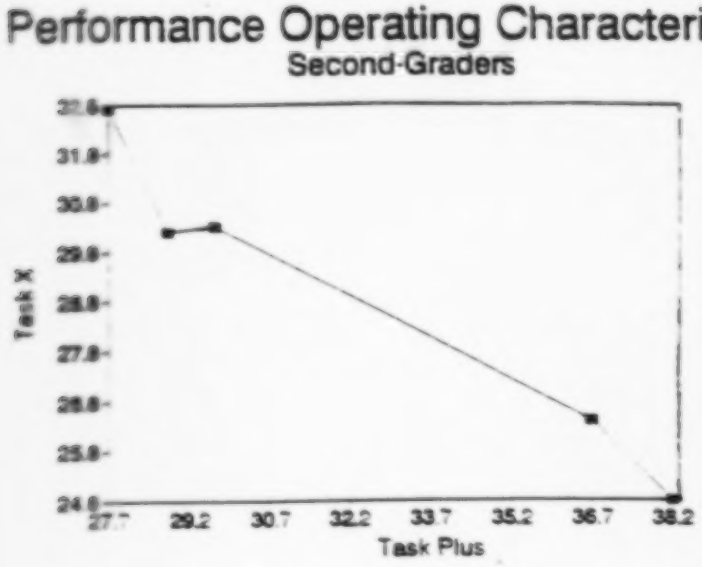


Figure 6


Performance Operating Characteristics
Second-Graders
Task X
31.8
30.8
29.8
28.8
27.8
26.8
25.8
24.8
27.7
29.2
30.7
32.2
33.7
35.2
36.7
38.2
Task Plus

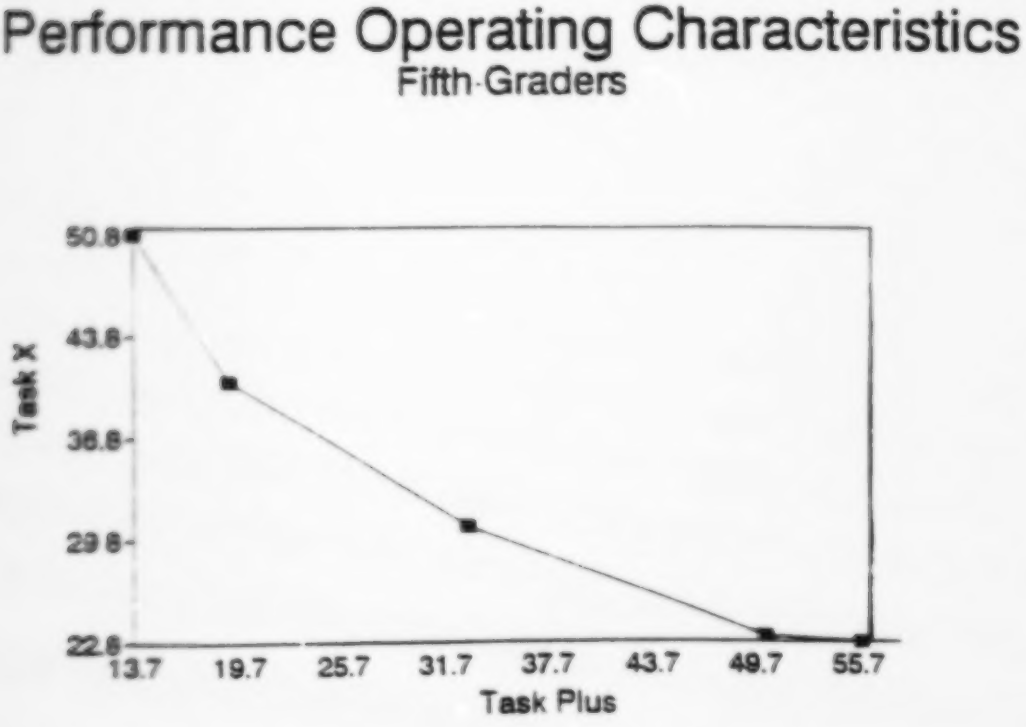

Performance Operating Characteristics
Fifth-Graders
Task X
50.8
43.8
36.8
29.8
22.8
13.7
19.7
25.7
31.7
37.7
43.7
49.7
55.7
Task Plus

Figure 7

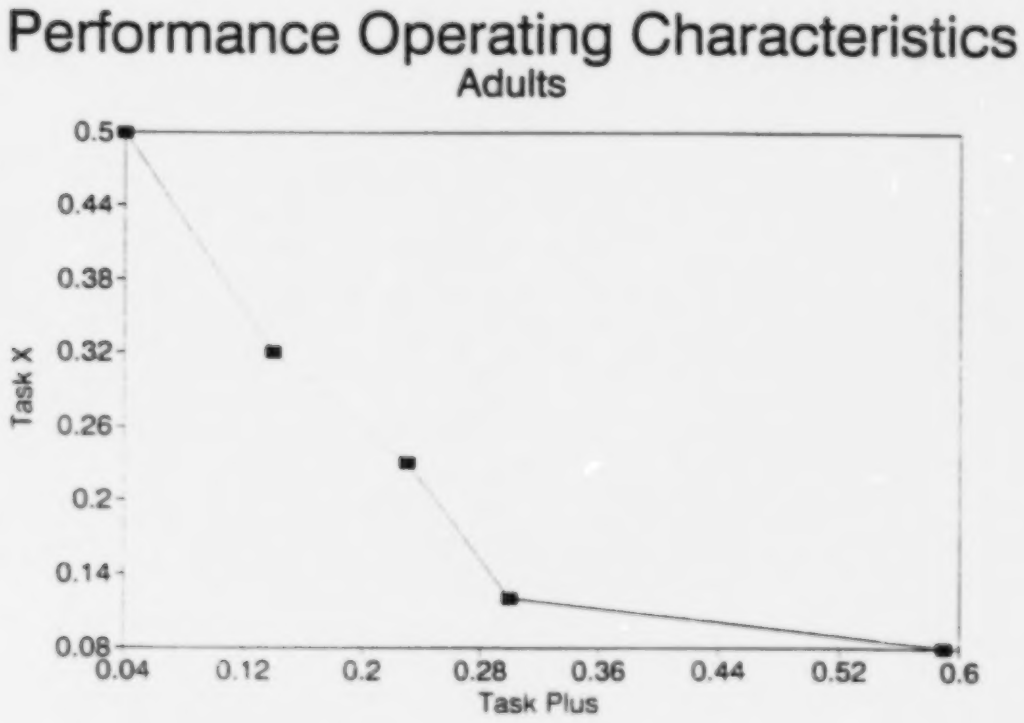
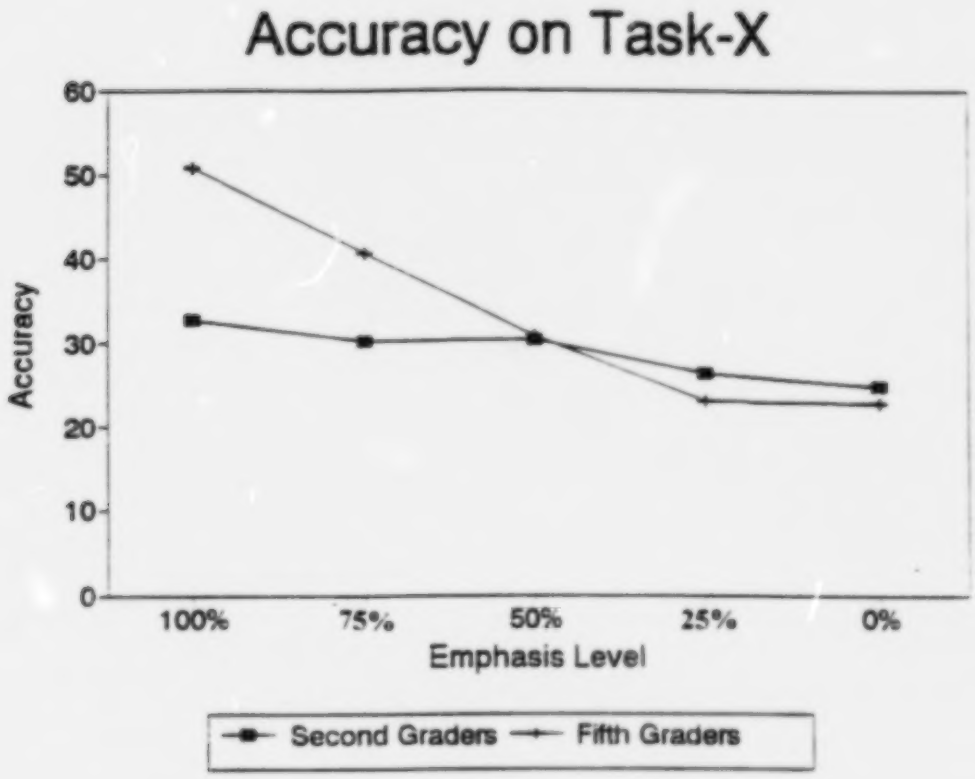

Performance Operating Characteristics
Adults
Task X
0.5
0.44
0.38
0.32
0.26
0.2
0.14
0.08
0.04
0.12
0.2
0.28
0.36
0.44
0.52
0.6
Task Plus

Figure 8


Accuracy on Task-X
60
50
40
30
20
10
0
Accuracy
100%
75%
50%
25%
0%
Emphasis Level
Second Graders
Fifth Graders

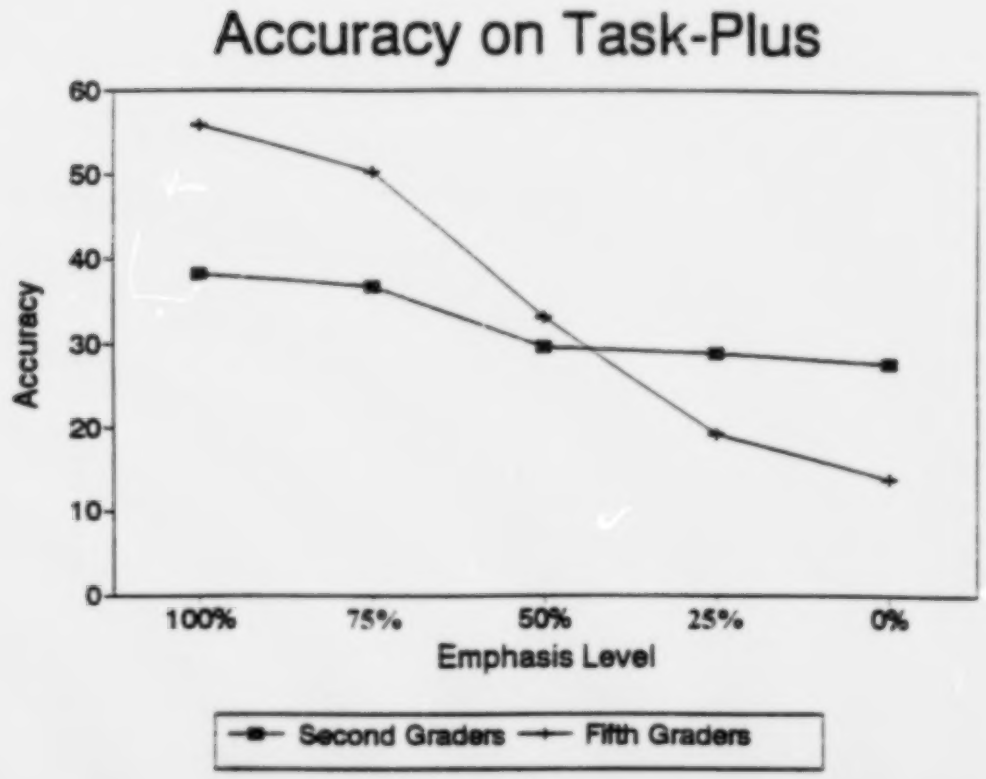
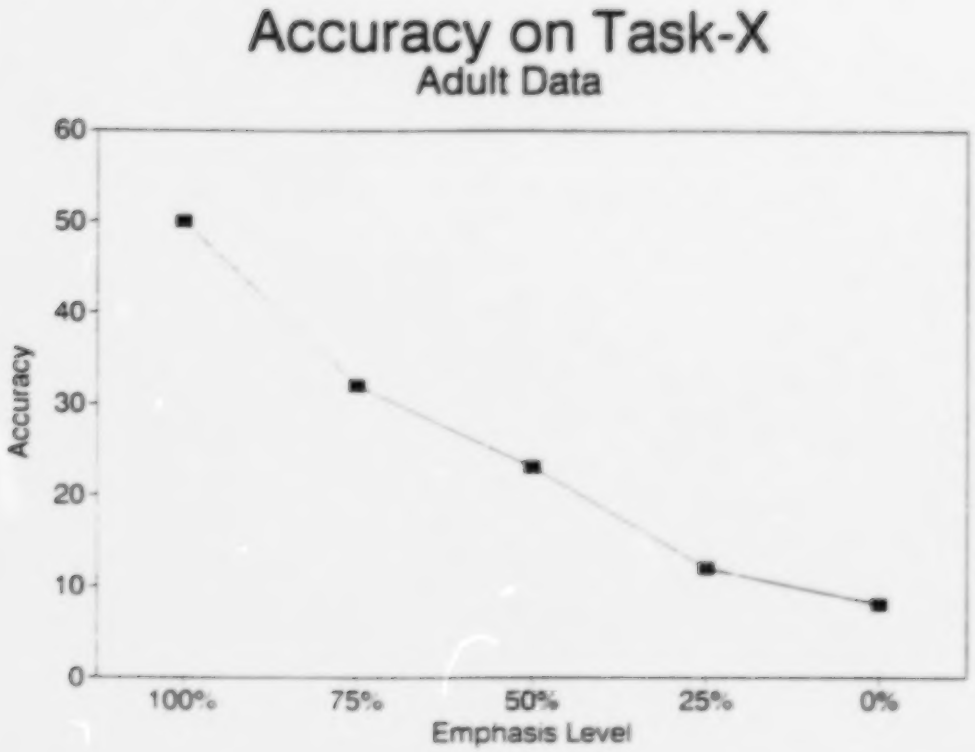

Accuracy on Task-Plus
60
50
40
30
20
10
0
Accuracy
100%
75%
50%
25%
0%
Emphasis Level
Second Graders
Fifth Graders

Figure 9


Accuracy on Task-X
Adult Data
Accuracy
60
50
40
30
20
10
0
100%
75%
50%
25%
0%
Emphasis Level

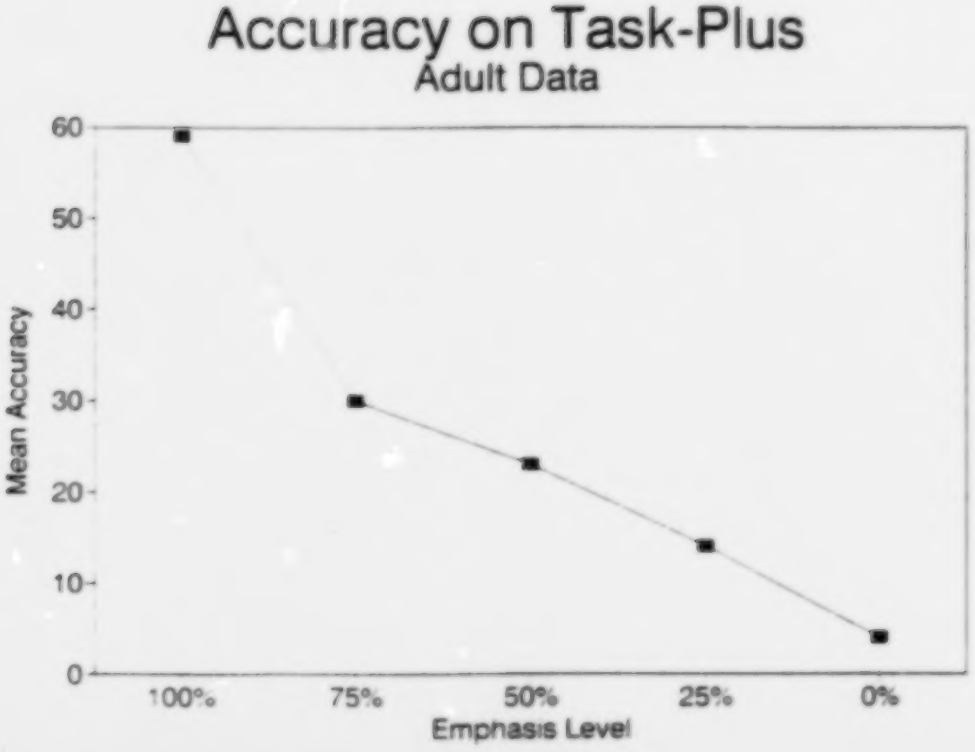

Accuracy on Task-Plus
Adult Data
Mean Accuracy
60
50
40
30
20
10
0
100%
75%
50%
25%
0%
Emphasis Level

Figure 10

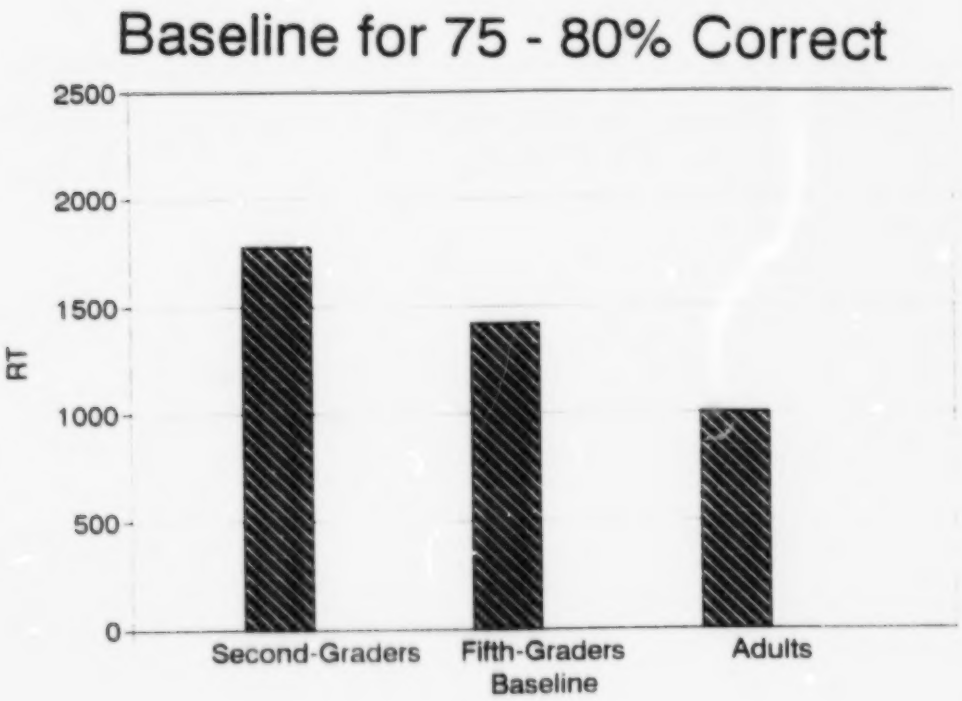

Baseline for 75 - 80% Correct
2500
2000
1500
1000
500
0
RT
Second-Graders
Fifth-Graders
Adults
Baseline

Figure 11

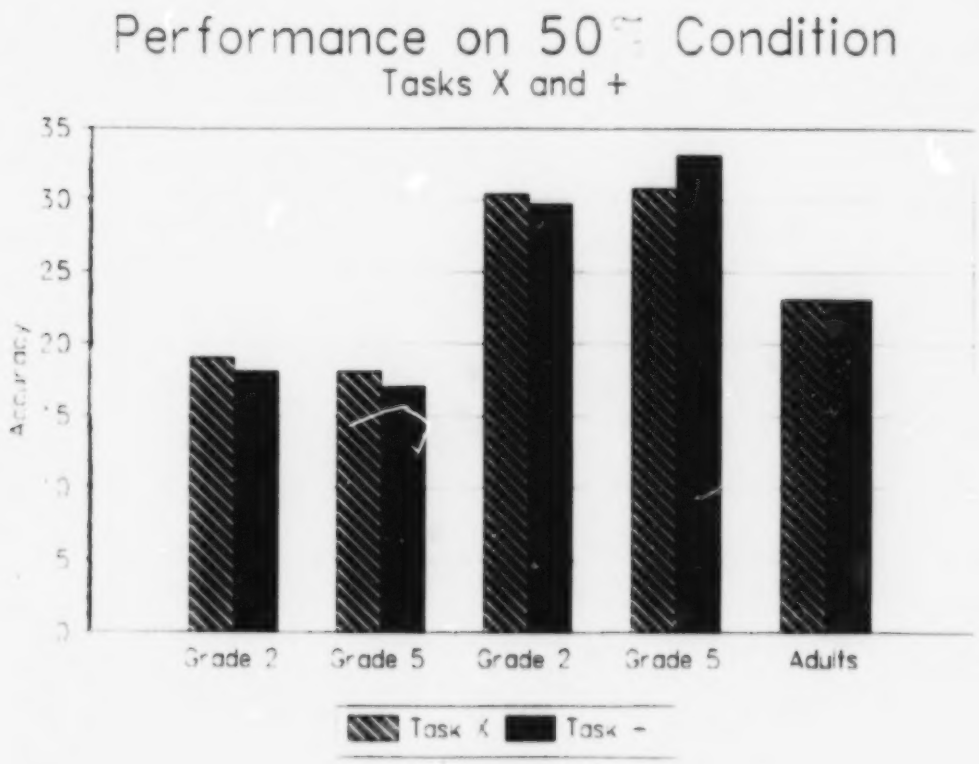
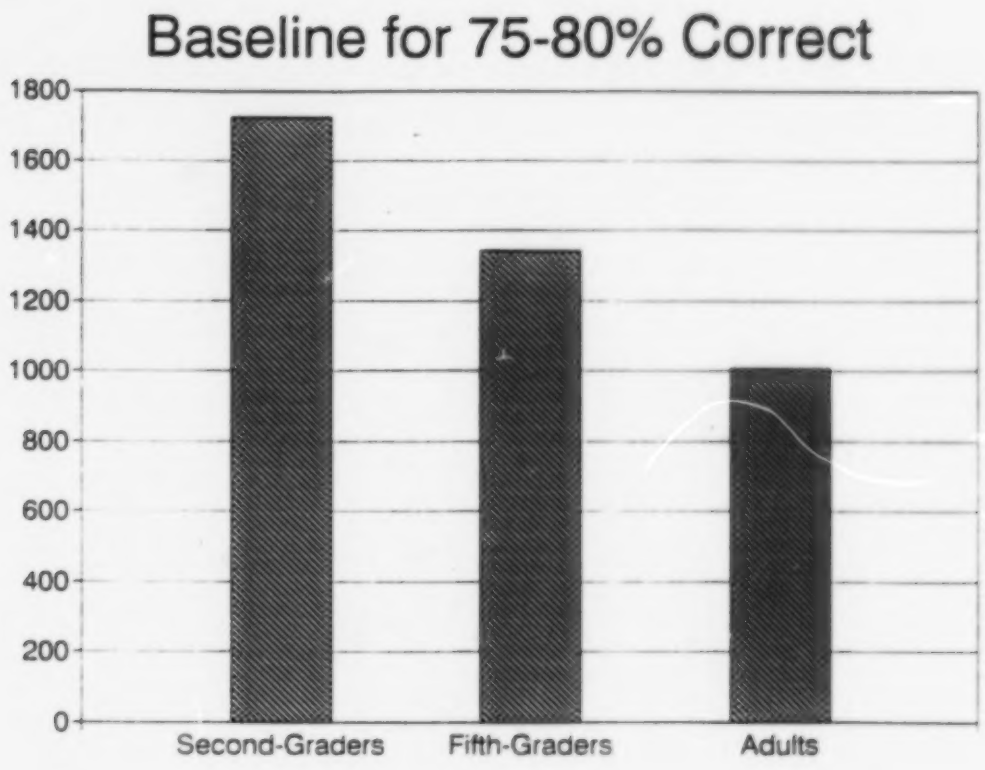

Performance on 50% Condition
Tasks X and +
35
30
25
20
15
10
5
0
Accuracy
Grade 2
Grade 5
Grade 2
Grade 5
Adults
Task X
Task +

Figure 12


Baseline for 75-80% Correct
1800
1600
1400
1200
1000
800
600
400
200
0
Second-Graders
Fifth-Graders
Adults